REMARKS

The claims have been amended in the attached Preliminary Amendment to place the application in proper U.S. format and to conform with proper grammatical and idiomatic English. None of the amendments herein are made for reasons related to patentability. <u>No new matter has been added</u>.
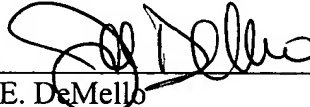
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2003P02901   MARKED-UP SPECIFICATION

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Description

METHOD FOR DAMPING PRESSURE OSCILLATIONS IN ~~THE~~ A MEASURING SIGNAL OF A LAMBDA PROBE

CLAIM FOR PRIORITY

TECHNICAL FIELD OF THE INVENTION

The invention relates to a method for damping pressure oscil-
lations in a measuring signal of a lambda probe, and in par-
ticular, to obtaining a correctively adjusted output signal
from the measuring signal, having a periodic pressure depend-
ence, of a lambda probe located in the exhaust of an internal
combustion engine, ~~whereby said measuring signal is sampled
in a time-slot pattern and averaged through totaling over a
specified summation period, said period corresponding to the
period of oscillation, dependent on engine speed, of pressure
pulsations of the exhaust~~.

BACKGROUND OF THE INVENTION

~~A method of this type is already known from~~ DE 37 43 315 A1
discloses oxygen ~~Oxygen~~ sensors mounted in ~~the~~ an exhaust
pipe ~~are~~ used to continuously determine the air/fuel ratio
with a high response rate in both the "lean" — lambda greater
than one — and the "rich" — lambda less than one — mixture
range. These, what are termed continuous or linear lambda
probes, operate according to the two-cell limit-current probe
principle and can be used as pre-cat probes for injection
controlling (lambda controlling), but especially for control-
ling lean-burn engines, for example Otto engines having di-
rect fuel injection.

The measuring signal of a lambda probe depends on a plurality
of variables, ~~particularly on~~ including the oxygen concentra-
tion to be determined in the exhaust ~~but also on~~ and the tem-
perature of the ceramic and the counter-pressure of the ex-
haust, with the degree of ~~the~~ pressure dependence of the

measuring signal being defined by the design of the probe. _A
distinction ~~must be~~is made where ~~said~~ the pressure dependence
is concerned between a static and a dynamic pressure depend-
ence. _Typical variations in the dynamic pressure dependence
of the measuring signal are within the significant range in
the case of continuous lambda probes and hence are an order
of magnitude higher than for what are termed binary lambda
probes. _The following concerns the damping or, as the case
may be, elimination of periodic pressure-related influencing
factors, especially in connection with continuous lambda
probes.

Pressure pulsations in the exhaust system are due partly to
the abrupt rise in the positive pressure curve triggered by
~~the~~ a pressure surge produced when discharge valves of a cyl-
inder are opened. _A waveform pressure curve is produced by
reflections or~~, as the case may be,~~ overlapping ~~of the~~ ex-
haust oscillation in the exhaust system until another pres-
sure surge occurs ~~accompanying~~ upon the cylinder's next ejec-
tion stroke. _An internal combustion engine operated by the
four-stroke method therefore produces a dynamic exhaust-
pressure curve having a periodicity of 720—°KW referred to
the crankshaft, which is to say dependent on engine speed.
The possibility of hardware-based filtering is limited, ~~as~~
because the frequency of the pressure-dependent interference
within the lambda signal depends on the internal combustion
engine's speed, and the central control device of the inter-
nal combustion engine must ~~also continue being~~remain suitable
for measuring rapid processes (lambda controlling on a cylin-
der-selective basis, for instance). _~~Owing to~~Based on the
above-described characteristic periodicity of the processes,
signal filtering requires averaging over a specific crank-
angle range of the internal combustion engine, for example,
in the case of a four-cylinder four-stroke internal combus-
tion engine having a single-flow exhaust system, 720—°KW/4 =
180—°KW.

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The generic method accordingly proposes an integration period or, as the case may be, summation period corresponding to the engine speed dependent period of oscillation of the pressure curve, in other words which is 180-°KW in the cited example

5 above. Above-cited DE 37 43 315 A1 also mentions the possibility of providing separate summation equipment to relieve the vehicle's microcomputer of the special function of signal filtering. _The following problems are in fact involved:

10 The known method for averaging obviously requires a relatively large amount of memory area to be reserved for the individual measurements of the lambda probe signal which are sampled in, for example, a 1-ms time-slot pattern and buffered in a ring memory. _For further processing of the lambda

15 probe signal, averaging would then be initiated at each instant at which a filtered output signal is required (say e.g., every 10 ms) by totaling a number N1 of buffered individual values and dividing the result by N1. _For the given sampling time-slot pattern the number N1 would exactly corre-

20 spond to the period of oscillation of the pressure curve. With this procedure, for a four-cylinder internal combustion engine, 50 individual values would at any rate have to be stored simultaneously in the ring memory in the case of for, say e.g., 600 revolutions; for a 6-cylinder two-bank system a

25 total of 67*2=134 individual values would accordingly have to be stored. _Averaging would furthermore always, which is to say at each update time, have to be carried out across the entire number of N1 measurements for the period to be considered so that, especially in the case of slow engine speeds,

30 the summation value would be formed several times over certain sections of the ring memory.

SUMMARY OF THE INVENTION
The invention relates to a method for obtaining a correc-

35 tively adjusted output signal from the measuring signal, having a periodic pressure dependence, of a lambda probe located in the exhaust of an internal combustion engine, whereby said

measuring signal is sampled in a time-slot pattern and aver-
aged through totaling over a specified summation period, the
period corresponding to the period of oscillation, dependent
on engine speed, of pressure pulsations of the exhaust.

The object of the invention is to describe a method of the
type mentioned at the beginning which is improveds particu-
larly in terms of memory-space resources and computing time
requirements.

Said object is achieved according to the invention by means
of a method according to claim 1.

According to onean embodiment of the invention, the procedure
method for signal evaluation is for the continuously--sampled
individual values of the measuring signal to be buffered in a
memory area of a memory of a control device for the internal
combustion engine and for averaging that includes a number
N1, corresponding to the summation period, of individual val-
ues sampled in the time-slot pattern to be initiated by the
control device at each instant at which an updated probe out-
put signal is required. According to the invention, however,
tThese steps are performed in such a way that totaling is
carried out across the N1 individual values block-by-block
and starts before the update time so that the block values
already formed continuously block-by-block up to the update
time and buffered, instead of the respective individual val-
ues, are used for calculating an average.

The signal conditioning method according to the invention is
therefore geared in particular to a favorable block algorithm
according to the formula

$$VLS = \frac{1}{N1}\left[\sum_{i=1}^{M1} VLS\_1ms + \sum_{i=M1+1}^{2*M1} VLS\_1ms + \cdots + \sum_{i=N*M1+1}^{N1} VLS\_1ms\right]$$

which ~~paves the way for~~ facilitates advantageous memory con-
figuring or; as the case may be, memory organization. _In the
above formula, VLS signifies the average, currently requiring
to be calculated, of the lambda probe voltage signal, VLS_1ms
signifies ~~in each case~~ a single non-linearized value of the
lambda signal sampled in, for instance, a 1-ms time-slot pat-
tern, N1 signifies the number, dependent on engine speed, of
individual values employed according to the period of oscil-
lation for averaging, N signifies a whole number, and M1 sig-
nifies the block length, which is to say the number of indi-
vidual values contained in a block.

The summation values already continuously formed block-by-
block over M1 measuring signals and the remainder of the N1-
(N*M1) measurements are accordingly used for calculating an
average VLS. _The storage requirements can thereby be reduced
to such an extent that only (N+M1) block values or~~, as the
case may be,~~ individual values have to be buffered. _There is
also a reduction in computing requirements. _The maximum pos-
sible engine speed and the updating rate of the averaged
measurement must be taken into consideration in determining
the number M1. _The relationships improved according to the
invention can be made clear using ~~as an~~, for example, the re-
cording of measurements over an extended period of time, in
this case 1 s, with updating being performed in a 10-ms time-
slot pattern and with averaging over N1=30 measurements
(M1=10):

Previously : 100*30 summations + 100 divisions
Invention : 100*10 summat. + 100*3 summat. + 100 divisions
Prev. storage requirements──: _50 values (~~as~~ at slow engine
                                         speeds it is poss.──ible for N1
                                         > 30)
Storage requirements, invention─: 10 (indiv.) values + 4 val-
                                         ues

In one embodiment, t~~T~~he invention is directed ~~at~~to segment-synchronous averaging. This means that, for totaling purposes, it should ~~at any update time basically~~ be possible, at any update time, to "look back" immediately and precisely

5 over the N1 last sampled individual values forming the segment currently being averaged of the ~~continuously~~ continuously-sampled individual values.

So that this can be realized in the context of block-by-block

10 totaling, according to the invention, it is advantageous to perform the following partial synchronizing ~~in a first step~~:

Block-by-block totaling is carried out over ~~in each case~~ M1 ~~sequentially~~ sequentially-sampled and buffered individual

15 values (M1 block) and is performed in a block time-slot pattern corresponding to M1 times the sampling time-slot pattern (sampling rate), as a result of which the updating rate can be synchronized with the M1 block time-slot pattern. In the event that the segment length is an integer multiple of the

20 block length, which is to say if N1=N*M1, segment-synchronous averaging can then be realized simply by using the ~~N~~N-buffered block values for calculating. It is, however, also possible to total the N-1 block values and all M1 individual values in the "last" M1 block ending at the update time.

25

In the case of a segment length N1 differing from the multiple of the block length, for averaging that is as segment-synchronous as possible, it is necessary in a second step to ~~carry out~~perform further partial steps amounting to taking

30 into consideration either at the end or at the beginning of the summation period only the required part of the relevant M1 block and not all individual values, at least not for current averaging, in order to exactly include N1 individual values in averaging despite the incommensurability prevailing

35 in such cases between block length M1 and segment length N1.

According to ~~a first~~one embodiment, it is advantageous in
these cases, where the number N1 does not correspond to a
multiple N of M1, to include the first N1-N*M1 individual
values in the last sampled M1 block that extend beyond a
5   maximum multiple N*M1 individually in a current averaging,
with the remaining individual values in ~~said~~the M1 block be-
ing left out of consideration here and ~~only~~included in the
averaging following the current averaging in the form of a
block value to be formed for this entire M1 block and buff-
10 ered. _In this embodiment, a defined number (1 to 9, for ex-
ample, in the case of an M1=10 block) of individual values
occurring immediately before the update time that are not to
be processed in the current summation period will accordingly
initially be left out of consideration. _A "dead time,"
15 amounting, in the example given, to ~~(~~1 to 9~~)~~ times the indi-
vidual value sampling interval (sampling rate), ~~must~~should
be accepted~~, it needs to be said,~~ in ~~the case of~~this ~~first~~
embodiment in terms of the average's actual currency at the
update time.
20

In a ~~particularly advantageous alternative~~second embodiment,
certain remaining, currently not required, individual values
temporally preceding the current summation period in an ear-
liest M1 block to be used for the current averaging are left
25 out of consideration. _Specifically, in ~~the~~cases ~~under con-~~
~~sideration~~where the number N1 does not correspond to a mul-
tiple N of M1, each M1 block is split into two partial blocks
B1 and B2, with the partial block B2 ~~containing~~including the
last N1-N*M1 individual values in the respective M1 block
30 that extend beyond a maximum multiple N*M1 and with the par-
tial block B1 ~~containing~~including the remaining first M1-
(N1-N*M1) individual values in the M1 block. _The two respec-
tive partial blocks B1 and B2 are furthermore totaled block-
by-block in a block time-slot pattern into partial block val-
35 ues MW_B1 and MW_B2, which are buffered in place of the re-
spective individual values. _Finally, the two partial block
values in the N last processed M1 blocks and the partial

block value MW_B2 of the M1 block processed immediately be-
fore the N last M1 blocks are then used for current averag-
ing. _A dead time is thereby avoided and averaging actually
takes place over the N1 individual values immediately preced-
5   ing the update time.

The advantages of a reduction in memory space requirements
facilitated by the invention can be realized in particular by
operating the memory area in the ring memory mode.
10

The method is particularly suitable in conjunction with
evaluating the measuring signal of a lambda probe which has a
continuous characteristic curve of said the measuring signal
and which is located upstream of a catalytic converter of the
15   internal combustion engine.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in more detail below with refer-
ence to exemplary embodiments and the figures in the draw-
20   ings, in which:

Figure 1 is a schematic of shows an internal combustion engine
having a lambda probe whose signal is to be conditioned.

25   Figure 2 is a chart showing for different speeds of the in-
ternal combustion engine the and time dependence of the signal
being conditioned, and.

Figure 3 is an organization chart of memory steps or, as the
30   case may be, computing steps shown symbolically in three lev-
els for processing individual lambda signal values according
to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

35   Figure 1 shows, in block diagram form, an arrangement in
which application of the method according to the invention is
applied. _The only components shown here are those necessary

for understanding the invention. _An air/fuel mixture is
routed to the internal combustion engine 1 through an intake
channel 2. _An air-mass meter (not shown here), for example,
can also be located in the intake channel 2. _The internal
5 combustion engine 1 is connected on the output side to an ex-
haust channel 3. _Provided in the exhaust channel 3 viewed in
the direction of exhaust flow is a first lambda probe 4, a
three-way catalytic converter 5 serving to convert harmful
exhaust constituents, and a second lambda probe 6. _The
10 fuel/air ratio in the exhaust ahead of the catalytic con-
verter 5 is determined with the aid of the first lambda probe
4 (control probe) having a continuous characteristic curve.
The second lambda probe 6 (monitor probe) serves, inter alia,
to check the catalytic converter 5 and typically has a binary
15 characteristic curve. _Located at a suitable position on the
internal combustion engine 1 is a speed sensor 7 which serves
to register the speed of the internal combustion engine 1 and
whose signal is routed to a central control device 8 over an
associated connecting lead.
20

To control and regulate the internal combustion engine 1 the
control device 8 can be connected via a data and control lead
9, shown only schematically, to further additional sensors
and actuators. _The control device 8 which, inter alia, con-
25 trols the injection process has, in a known manner, a micro-
computer 10, corresponding interfaces for signal conditioning
circuits, and an input/output unit. _The microcomputer 10 in-
cludes a central processing unit (CPU) that performs the
arithmetic and logical operations applying the supplied data.
30 The programs and reference data required for this are sup-
plied by a read-only memory (ROM). _A random access memory
(RAM) 11 serves, inter alia, to store the data supplied by
the sensors until it is called up by the microcomputer 10 or
replaced, which is to say overwritten, by more current data.
35 The method according to the invention serves essentially to
spare the resources of said the memory 11, which are burdened
by the necessary buffering in an area of said the memory 11

of values which are associated with the corrective adjustment
of the pressure dependence of the measuring signal of the
lambda probe 4.

5   The top part of Figure 2 shows a periodically time-dependent
voltage signal UM representing the unfiltered measuring sig-
nal of the lambda probe 4. _The thin vertical lines indicate
the pattern of the updating rate T of the output signal, with
averaging over a period of oscillation TP, dependent on en-
10 gine speed, of pressure pulsations of the exhaust taking
place every 10 ms in the example shown (four-cylinder engine
having a single-flow exhaust system). _~~Said~~ The_updating rate
T=10 ms is synchronized with the M1 block time-slot pattern,
which is in turn based on the 1-ms time-slot pattern selected
15 here for sampling .individual values. _Each M1 block therefore
~~contains~~ includes_10 individual values in the example given.
The filtered output signal, calculated in each case at the
update times t_n or, as the case may be, $t_{n'}$, is represented by
the voltage values UA indicated by dots in Figure 2. _As can
20 be expected for a properly controlled operating state, the
averaged lambda output signal therefore exhibits a constancy
across the different engine-speed ranges D1 or, as the case
may be, D2, marked by the thick vertical lines, of the inter-
nal combustion engine 1.
25

As averaging has to take place precisely over one period of
oscillation TP of the pressure pulsations, a length of summa-
tion dependent on engine speed, which is to say TP1 for D1
and TP2 for D2, is first determined by the control device 8.
30 A defined number of single non-linearized values of the meas-
uring signal corresponds to this summation period, depending
on the selected sampling rate of the measuring signal, in
this case 1 ms. In the example shown in Figure 2, the left-
hand part of the figure shows a range D1 having an increased
35 engine speed (1,666 revolutions/min, for instance) where a
summation period of 18 ms is calculated so that, for averag-
ing, it is necessary in each case to total, across a segment

totaling N1=18, individual values VLS_1ms. _At each update
time t_n, in this case, for instance, at the end, marked by
the left-hand thick line, of the engine-speed range D1, it is
necessary in each case to total across precisely 18 of the
5   past individual values, as indicated in Figure 2 by means of
the 18 short lines and the arrow above them symbolizing the
retrospective view adopted for averaging. _On the other hand,
there is a relatively longer summation period for the area
between the two thick vertical lines in Figure 2 owing to the
10   range D2 represented there having a slower engine speed and,
in keeping with this, there is a correspondingly greater num-
ber N1 of individual values to be totaled, in the example
shown here (D2=714 revolutions) N1=41. _The segments n' or~
~as the case may be,~ n'-1 to be observed at the update time
15   $t_{n'}$ and, immediately preceding this, $t_{n'-1}$, are indicated in
the engine-speed range D2 in Figure 2, again ~by means of~using
arrows.

According to an embodiment of the invention, the 18~, for ex-~
20   ~ample,~ individual values VLS_1ms in the faster engine-speed
range D1 shown, which are to be totaled, are not all stored
in the buffer until summation. _Rather~ it is the case that~,
the first 10 temporarily first sampled individual values in a
segment are written successively to the buffer, where appli-
25   cable, with the individual values in a (M1=10) block created
during immediately preceding averaging being overwritten, and
are then processed block-by-block, ~which is to say are~i.e.,
they are totaled into a block value at the end of the rele-
vant (M1=10) block time interval. _This individual block
30   value representing the filtered information, assembled from
10 individual values, about the average of the measuring sig-
nal in the time interval of the given block, is retained in
the buffer until the next updating, while the 10 buffered
"old" individual values are successively overwritten in the
35   ring memory mode by the 10 individual values in the next
(M1=10) block.

According to a first embodiment of the invention, in the ex-
ample ~~selected~~ shown in Figure 2, it is possible (in the D1
range) to proceed in such a way that the first (in this case~~:~~
single, since N1=18=1*10+8, so~~:~~ N=1) block value is buffered,
and that in the next block time section the 8 individual val-
ues still missing from the segment of the N1=18 individual
values to be used in total for averaging are initially writ-
ten one after the other to the positions previously occupied
by the old individual values. It is also possible ~~,~~ that, in
keeping with the time-slot pattern, two further individual
values are sampled and written, and that due updating of the
average is carried out on completion of said "last" block
time section in such a way that the individual block value
and the individual first 8 individual values in the last cre-
ated (M1=10) block are totaled. In parallel with this, ~~all~~
10 individual values in the last created (M1=10) block are
totaled into a block value, used during the next updating,
and buffered. In the example given, the "current" average
determined at a specific update time t_n is therefore,
strictly speaking, already 2 sampling intervals "old", inter-
vals which according to the specified synchronizing have to
be waited out.

Figure 3 ~~relates to~~ illustrates a second embodiment of the
invention that can be used in cases N1≠N*M1 as an alternative
to the method discussed in connection with Figure 2. A sin-
gle-flow exhaust system of a four-cylinder engine running at
1,304 revolutions per minute, updating in a 10-ms cycle, a
sampling time-slot pattern of 1 ms, a block length M1 of 10
individual values, and a summation period of 23 ms, which is
to say a segment length N1=23, are assumed in the following
explanations by way of example.

The top level ("single-value memory") of Figure 3 relates to
the sampling or~~, as the case may be,~~ buffering of the~~, in
each case,~~ 10 individual values in a block ~~currently~~ to be
processed. ~~T~~Shown ~~there is only~~ the last ~~of the~~ four blocks

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considered ~~in~~ are illustrated in Figure 3 by way of example,
with ~~said~~ the last block, as indicated symbolically, having
been divided, as were the three blocks processed before it,
into a first partial block B1 ~~containing~~ including 7 individ-
5   ual values and a second partial block B2 ~~containing~~ including
3 individual values. Specific dividing in this way is due,
in the example being considered, to the fact that, in accor-
dance with N1=23=2*10+3, a partial block B2 having 3 individ-
ual values is required for further calculation.
10

The middle level in Figure 3 shows four pairs of partial
block values MW_B1 and MW_B2 (the end digit added in the fig-
ure relates to origination from one of the four individual
value blocks; the lines symbolizing the block values are not
15   to be referred directly to the time axis of the lower level),
which were generated one after the other ~~in each case~~ from
the corresponding individual value block among the four M1=10
individual value blocks and buffered. For example, the first
7 individual values in the first block were totaled into the
20   partial block value MW_B1_1 and buffered when ~~all~~ 10 individ-
ual values in this block had been sampled and buffered, while
the last 3 individual values in this block were totaled into
the partial block value MW_B2_1 and buffered. The ~~no~~ no-
~~longer~~ longer-required associated individual values can then
25   be overwritten by the new individual values in the next, sec-
ond block. The new individual values are then processed into
partial block values MW_B1_2 and MW_B2_2 in a manner analo-
gous to the process for the first block.

30   ~~Only t~~The partial block values buffered according to the mid-
dle level are required for calculating the average, the re-
sults of which calculation are represented symbolically by
the lower level ("measurement output") in Figure 3. As indi-
cated schematically for two update times by ~~means of~~ lines
35   between the middle and lower level, the current average due
after, for instance, 30 ms is calculated by totaling the two
partial block values arising from the third block immediately

preceding the update time, the two partial block values aris-
ing from the second partial block, and the partial block
value MW_B2_1 arising from the first block (and dividing the
result by N1). It is thereby possible, at the respective up-
5   date time, immediately to look back at the required exact
number N1, in this case N1=23, of individual values immedi-
ately preceding the update time.

It is advantageous if in the case of In a preferred embodiment
10 of the invention, in at least one of the processed M1 blocks,
one of the two partial block lengths is also buffered until
current averaging.

The use of resources and computing time required by the cal-
15 culations involved in signal conditioning can, as described,
be significantly reduced through block-by-block pre-
processing of the individual values of the measuring signal
of the lambda probe, the main impact of this being a savings
in memory space resources. A factor to be taken into account
20 here is that calculating in a 1-ms time-slot pattern and pro-
viding, for example, (around) about 140 memory locations for a
two-bank system places heavy demands on the overall resources
of an engine control. The advantage according to the inven-
tion is therefore brought more to bear in advantageous for
25 multi-bank systems.